Human Performance Concerns for the TRACKWOLF System

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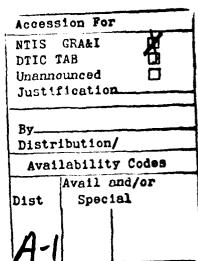
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This report presents findings from site visits to two operational systems (OUTS and TRACKFINDER), which are predecessors to the objective TRACKWOLF system under development. The purpose of the site visits was to obtain "lessons learned," operator workload estimates, and critical high-driver tasks. These data were used as a baseline for comparing operator capabilities and as a precursor to use in TRACKWOLF operational tests. Findings indicated significant frustration with equipment operations and communication capability of OUTS and TRACKFINDER. This was also revealed by a high rating on the workload scale (NASA-TLX) on frustration and temporal demand subfactors. Over 50% of the tasks were judged high workload and difficult cognitive load for operators. Results have been provided to proponent combat developer and trainer personnel.

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HUMAN PERFORMANCE CONCERNS FOR THE TRACKWOLF SYSTEM

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HUMAN PERFORMANCE CONCERNS FOR THE TRACKWOLF SYSTEM

Introduction

AN/TSQ-152, or TRACKWOLF, will be the echelon above Corps (EAC) high frequency (HF) collection and direction-finding (DF) system. It will be a mobile, ground-based, modular, highly automated system which will replace the AN/MSA-34 - Operational Unit Transportable System (OUTS); the AN/TRD-23A, and the AN/TSS-11 - TRACKFINDER (an engineering development model of the DF subsystem); and be comprised of two independent but interactive communications intelligence subsystems--collection and processing subsystem and DF subsystem. The introduction of the new TRACKWOLF technology is a necessary step forward to replace the outdated equipment and bring state-of-the-art electronic and computing capabilities to the EAC HF COMINT (communications intelligence) mission.

An important question in this process is to determine the impact, if any, on operator performance capability and training for the new system. This report describes a research effort by the US Army Research Institute (ARI) at Ft. Huachuca to provide data to the combat and training developer at the US Army Intelligence Center and School (USAICS), to assist in assessing personnel concerns related to soldier performance on the TRACKWOLF system.

Method

Data to address personnel and training concerns for the TRACKWOLF system was derived from two sources: (1) baseline systems observations (OUTS and TRACKFINDER), and (2) analysis of baseline systems tasks as potential TRACKWOLF tasks using workload measures, human performance elements, and MI (Military Intelligence) MOS (Military Occupational Specialty) capability assessment. The baseline systems observations involved structured subject matter expert (SME) interviews with operators from each MOS, and observations of their performance at two unit locations, which produced "lessons learned" and suggested solutions for system improvements in a number of soldier-system areas. In addition, these system operators in each MOS were given a multidimensional workload rating scale (NASA Task Load Index, Version 1.0; Hart & Staveland, 1988).

Data collection occurred during site visits made to the two units which have the OUTS and TRACKFINDER systems: Company A (HF/DF), 204th MI Battalion, 66th MI Brigade (Augsburg, FRG), and Company A (HF/DF), 201st MI Battalion, 513th MI Brigade, Vint Hill Farms Station, VA. The 201st was the only unit to have the

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TRACKFINDER. Structured interviews were conducted and observation of system operations occurred during FTXs (Field Training Exercise) as well as offline with 28 personnel in operator positions representing five MOSs: 98C - Traffic Analyst (N=7); 05K - Non-Morse Intercept (N=3); 05H - Morse Intercept (N=7); 98G - Voice Intercept (N=4), and 05D - Emitter Locator/Identifier (DF) (N=7).

The analysis of baseline tasks as potential TRACKWOLF tasks consisted of: computation and analysis of overall workload scores on each of 31 tasks currently performed, profile analysis of sources of workload for each operator position, a crosswalk between measures of workload and psychological difficulty of the tasks, and a crosswalk between MI MOS capabilities as currently selected and trained with the demands of the 31 system tasks. The 31 operator tasks were derived from the operator SMEs interviewed at the system sites.

Results

Baseline Systems Observations

The interview and observational data for OUTS and TRACKFINDER, is presented in Table 1, which is a digest of all comments, observations and suggested solutions. Overall system observations are reported first, followed by data specific to each MOS operator position for the OUTS and TRACKFINDER systems. This digest contains items ranging from detailed human factors concerns regarding the equipment and equipment interfaces, to opportunities for simplifying or eliminating operator functions and tasks.

Overall observations summarize recurring themes found in more detail in the observations from the five MOS positions. These themes are: technology is too old, data processing very time consuming; system documentation and users guides are too complex; automation is overly complex for the job; not enough personnel to staff the system; and communications difficulties. Suggested solutions range from specific hardware and software fixes to concepts of automation and function allocation that would eliminate certain duplications, redistribute tasks, and potentially eliminate certain MOS operators. Often cited examples are: allowing all operators to do simple DF instead of the 05D MOS; allowing collectors to do simple, initial unit identifications and analysis prior to the traffic analyst (98C); and providing working aids in databases for report formats and transmissions.

Among the MOS specific observations, the comments from the 05D operators are voluminous and detailed in comparison to the others. The 05D has 28 citations in eight separate categories, most of

Table 1

Observational and Interview Data From 28 Subject Matter Experts on the OUTS and TRACKFINDER Systems (Collected 1989)

Upgraded Outs (TRR-27)

Description:

- 05H (Morse Intercept) - 3 to 5 per shift

- 05K (Non-Morse Intercept) - 1 to 2 per shift

- 98C (Traffic Analyst) - 2 to 3 per shift

- 98G (Voice Analyst) - 2 per shift (Augsburg only)

- Supervisor - 1 per shift

Contains 5 automated workstations (3 for 05H and 2 for 05K), 98C has no automated support (although in Augsburg they are trying to develop their own automated database working aids, but it is a very slow process and not convenient to use).

Overall Observations:

1. 1950's technology in old version before upgrade; completely manual.

2. Old version was too slow and time consuming to handle the data that required processing.

3. System documentation and users guides are too complex and technical.

4. Automation as it is currently done makes the tasks too complex; automation has added complexity to the 05H and 05K jobs.

5. Not enough people to staff the system.

6. Comms are a problem in communicating between vans (TRACKFINDER to main TRR-27 or to the outstation). Comms are not the same problem in Augsburg since everyone is inside the same facility. In the upcoming TRACKWOLF small vans will be linked together with fiber optic nets for communication so comms could be a big problem.

Tab₁₂ 1 (continued)

Suggested Solutions:

1. Use reconfigurable workstations that are task oriented not MOS
oriented (Fireworks at ESL is a good example of this concept).

2. Improve interface using 'direct manipulation' commands rather
than function keys (e.g., Fl=print, F2=edit); provide software
dials rather than hardware dials; multiple windowing capability.

3. Provide more on-line help; simplify user guides.

4. Simplify and reduce the number of commands needed to perform a
task. (Better to have one prompt for each time of information).

5. Reallocate functions among the MOSs; automate functions to the
extent possible thus reducing the number of operators and workload
demands. (Automate Morse collection if possible, automate 05K to
extent possible). Focus redesign on high workload tasks.

6. Simplify DF and allow the intercept operators 05H, 05K, and
98G to perform this task. (IGRV is a good example of DF done by
intercept operators). Have system take LOBs automatically when
the operator initiates it with a key press. The operator can edit
the LOBs or pass to a 05D for editing difficult fixes if required.
05Ds work only one shift in Augsburg anyway so only about a third
of all intercepts get DF'd currently.

7. Provide a Local Area Network to pass data between operators
and analysts rather than using isolated workstations and passing
printouts.

8. Provide working aids in an automated database accessible to
every operator so they can do their own initial identifications of
unit and activity before passing it to 98Cs (maybe in place of 98C
"analysis"). Working aids should be two kinds: unit/call
sign/activity type look-up (same as they have now manually) and a
dictionary/glossary in the appropriate language (e.g., Russian).

9. Reduce duplication of effort. Provide capability for
operators to write up traffic in report format (Strum or Kleight)
and pass automatically to 98C for reporting. 98C should be able
to collect together all formatted traffic sent by the operators
into one report and edit as required before sending out.
(Currently they have to screen then retype everything sent to them
by the operators plus the DF from the 05Ds and it is very time
consuming).

Table 1 (continued)

05K

Position Characteristics:

- 1 to 2 per shift.

- 2 workstations, but one doesn't have a CRT and keyboard.

- Operators were learning to use the system during the exercise so workload data was probably biased.

- No real mission for 05K in Augsburg, only one in unit.

Observations:

1. Printer was not working; also software problems.

2. Dial is too high for searching freqs; requires full arm extension above the head; search cannot be done on computer with cursor (like 05Hs).

3. User's manual is too complex to be useful.

4. Power switch is at knee level in front of seated operator and results in operator accidentally shutting off system.

5. Job is more complex with automation; e.g., files, floppies, more functions, more keystrokes and operations required to perform tasks.

Suggested Solutions:

1. Streamline tasks, simplify interface, reconfigure workstation.

Alternately,

2. Automate the position. The 05K job has potential to be completely automated by using a scanner to locate the signals, software to determine if it is a teletype signal, to digitize it, and send it to the 98Cs for analysis.

Table 1 (continued)

05H

Position Characteristics:

- 3 to 4 per shift.

- 3 workstations; each one has a CRT, keyboard, 2 receivers, a printer (upgraded TRR-27).

- Workstations in Augsburg are completely manual with a typewriter and a receiver.

- 2 operators on general search, one on directed search.

- Operators were learning to use the equipment during the exercise.

- All tasks have about equal workload.

Observations:

1. Printer was not working; software problems; overheating of computers (no tolerance to temperature ranges).

2. Durability and mobility of equipment is a big problem. (TRQ-32 is durable, mobile, and provides multiple capabilities such as jamming, DF, copy all at the same time).

3. Job is more complex as it is currently automated. Only need capability to search freq, listen, type, and print. It currently requires too many operations and keystrokes to perform a task. Also should have capability to prepare traffic in report format with a message mask, working aid database for doing indents, and capability to pass formatted traffic to 98Cs. Also automatic DF capability.

4. Workstation is poorly designed. Keyboard is too high, dial for searching is too high, printer is too low to see what is printed or when paper gets stuck, pull-out worktable for the keyboard collapses when it is bumped.

5. User's manual is too complex and hard to use.

6. Need better help functions or "cheat sheet" for commands.

7. Error messages are not informative.

Table 1 (continued)

8. Operators can do some of the analysis but working aids (i.e., the database) are not available.

9. Need edit function for copied code (although it might not be included for security reasons so that the code cannot be altered by anyone after it is entered).

Suggested Solutions:

1. Simplify automation; require fewer operations to perform tasks.

2. Rearrange workstation and interface (better to have reconfigurable workstations and interfaces).

3. Use LAN to receive tasking and disseminate traffic to 98Cs.

4. Provide working aid databases on the system so 05H can do analysis if time is available.

5. Simplify DF. Have 05H, 98G, and 05K do DF. All that is required is taking LOBs and editing LOBs. Have system take LOBs automatically while 05H is copying code. Edit LOBs after copying code. If it is a difficult signal or operator is pressed for time, can send it to an 05D for editing.

6. Provide automated scanning capability where freqs can be scanned automatically.

7. Use automatic Morse decoder where feasible.

98G

Position Characteristics:

 - 2 per shift in Augsburg (none at VHF).

Observations:

1. No automated support whatsoever.

2. Do a lot of identifications (rather than 98Cs doing it), but have to use manual working aids, very slow.

Table 1 (continued)

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3. Tape recorder does not operate immediately when it is
initiated so always lose some voice (98Gs always turn on recorder
when they have found traffic of interest, then go back and listen
to it again when they are writing up the traffic for reporting to
send to 98Cs).

4. Takes 30-60 minutes to prepare traffic in a Strum format for
reporting at end of shift for each operator (then 98C has to
retype all info over again to report it).

5. Volume cannot be adjusted on the new recorders recently
received.

Suggested Solutions:

1. Automate position to provide capability to search for signals,
transcribe and edit, record, DF, write a report using a report
mask (so that when they transcribe it would be in the reports
mask; then they can edit as needed), send messages to other
operators and a report to 98C over the network.

2. Working aids should consist of both identification information
and language dictionary/glossary.

98C

Position Characteristics:

- 2 per shift.

- Completely manual.

- Use microfiche for database info at VHF, documents at
  Augsburg.

- Use standard typewriter for reports.

- 10 to 30 minutes to process an individual piece of traffic.

- Integrate traffic from all operators and DF into one report.

- 5 to 10 minutes to do a Kleight report (for urgent info);
  about 30 minutes to do a Strum report (summary of info sent
  periodically).

- Prepare tasking once per shift but it is a continuous
  process.

Table 1 (continued)

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     - Prepare report once per shift; send report to TCAE.

     - Report only 10% of the text in an 05H traffic report (at VHF).

Observations:

1. No automated support whatsoever; uses 1950's technology.

2. Reporting is very time consuming, have little time for doing identifications.

Suggested Solutions:

1. Should receive traffic reports from intercept operators via e-mail not print-out (as is currently done).

2. Need automated data base and correlating/referencing (i.e., database management) capability rather than microfiche.

3. Need easy way to enter new data received from higher commands into working aid database (e.g., from diskette).

4. Need automated capability for preparing and sending reports; split screen with traffic in one and report mask in other.

5. Need automated capability to prepare tasking messages for 05H, 05K, and 98G.

6. Need capability to send tasking messages to intercept operators via e-mail.

7. Need capability to easily enter into the system the new tasking messages received from TCAE. (Actually, they would just want to edit the TCAE's message and sent it to the operators).

8. Need smaller, portable, durable computers.

TRACKFINDER

05D

Position Characteristics:

     - Uses Single Site Location (SSL) technology; learned OJT.

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Table 1 (continued)

- Uses 2 TRACKFINDERS (main and outstation) to ensure greater accuracy.

- Main TRACKFINDER has 2 operators (should have 3); outstation has 1 to 2 operators.

- Overall time to do DF is 1 1/2 to 3 minutes; tip time to flash time (flash time means locate signal) is 15 to 60 seconds, flash time to fix time is 1 to 2 minutes.

- Top operators under pressure can do it all in 60 to 100 seconds.

- Capable of 20 to 24 DFs per minute.

- 3 to 120 DFs done per shift on the exercise--not close to capability.

- Time to set up the system is about 4 hours total depending on the number of people available; 1 1/2 hours to set up the antennas.

- About 30 hours of OJT is required for minimal proficiency; 800 hours to be capable of troubleshooting; about 2 weeks of formal (OJT is provided only between 3 and 100 signals per shift).

Observations:

Interface:

1. Menu selection is cumbersome; have to cursor through everything line by line.

2. No feedback on whether fix from main TRACKFINDER is integrated with outstation fix; operator never knows whether it is done since it is automatically done by the system; thus could be sending 98C a DF based on one fix only (difficult to find out although it can be verified by looking in DB).

3. Need help functions, particularly for troubleshooting (correcting) a problem (after receiving an error message).

4. Error messages are not informative for non-experts.

Table 1 (continued)

Workstation and Shelter:

1. Need shelving.

2. Need access panels for cables.

3. DF and comms receivers are not easily accessible; have to get up and walk around workstation to get to them.

4. Need fold down table for writing; not enough work space.

System Operations:

1. System locks up occasionally; completely down for several minutes at a time.

2. Magnetic tape recorder does not work.

3. TRACKFINDER is more complex than it needs to be; need simplification of overall task configuration.

4. Too much redundancy with Net Controller (NC) doing a location request containing tech data and passing it to the operator at the next workstation for DF.

5. System cannot perform more than one function at a time; cannot process more than one signal or one mail; completely sequential operations.

6. Need queuing for tips and location requests; NC cannot request another DF until operator has finished DFing the current signal; if NC does send a request, system drops it.

7. If operator does not begin to DF a signal in 20 seconds, system does not allow operator to do DF and NC has to re-request DF (i.e., send another location request).

8. When rebooting, system resets tip # back to one so it is possible to have multiple tip #1's in one day.

9. System is too complex; too many pieces to fail--such as HF comms, VHF, encryption.

10. Can't troubleshoot problems (i.e., correct errors or system failures) unless operator is very skilled and knowledgeable about the system.

Table 1 (continued)

System Documentation:

Manuals are too complex; geared for operator who is very skilled on the system; manual is too technical to be useful.

System Set Up:

1. Magnetic declination is confusing and difficult; have to trick the system by entering false #'s to get accurate readings.

2. Have to come back to shelter to test whether placement is correct; need some way to assess it while in the field.

Functions:

1. GPS that informs operator of own location is unnecessary (unless system is very mobile).

2. Need keyboard command to adjust (fine tune) antennas for better signal.

3. Need computer game to practice Morse and other skills during slow times; could be automatically disabled when a tip comes in.

4. Need auto receipt of tip offs and tech data from 98Cs--too much redundancy in retyping data and comms are too frustrating.

Comms:

Comms are extremely frustrating; too much failure; down too often; too many components to fail (VHF).

Other:

1. System check with known targets is time consuming; should be automated.

2. Extremely high degree of frustration with the system resulting from comms, error correction, and system setup.

Suggested Solutions:

1. Streamline System:

   - Reduce time and redundancy by eliminating the NC position and use two operators instead.

Table 1 (continued)

- Have system automatically begin DF when signal is located; let operator fill in other data if needed while system is taking LOBs; don't make operator wait to do DF until after all tech data is entered.

- Have tip off and tech data sent from 98Cs automatically so that operator does not have to reenter data.

- Automate system check with known targets; operator can enter known targets into a database.

- Simplify operations; one key processing of DF, automatic receipt of tip off and tech data from 98C, automatic reporting of results to 98C/TCAE; eliminate phone calling (as in TRAILBLAZER).

- Improve comms with outstation.

Alternately,

2. Eliminate operators at TRACKFINDER sites; make them non-staffed systems except for a maintainer and 05D(s) for set up. Simplify DF so that it can be done by intercept operators at main site (TRR-27) thus eliminating all extra, redundant work such as tasking, sending tech data, and comms. (IGRV is a model for this set up). Have one 05D at main site for DF of difficult signals as needed; intercept OPS can pass LOBs to 05D if help is needed.

which are very equipment and workstation design oriented. In comparison, the 05H operator has nine citations, 05K and 98G five citations each, and the 98C has only two. The 05H and 05K have difficulties with automation and desire simplification of interfaces, while the 98G and 98C lack automation support and request it to simplify and streamline their work. 98G and 98C concerns focus largely on time demands of report production which tends to interfere with the more analytical aspects of the job.

Analysis of Baseline System Tasks

Operators were also provided the NASA-TLX workload assessment scale and asked to fill it out for 31 primary tasks associated with their duty positions on the OUTS and TRACKFINDER. The NASA-TLX is a widely used multidimensional rating procedure that provides an overall workload score based on a weighted average of ratings on six subscales: (1) Mental Demands, (2) Physical Demands, (3) Temporal Demands, (4) Own Performance, (5) Effort, and (6) Frustration. Definitions of these subscales are listed in Table 2. The operator first performs pairwise comparisons of the relative contribution of each subscale to their overall workload, and then provides numerical ratings of that scale's contribution to task workloads. Two types of indices are then computed: (1) operator workload profile showing the relative importance of each subscale for that position, and (2) workload value by each task, computed from a weighted average of subscale contributions and ratings on a 100 point scale.
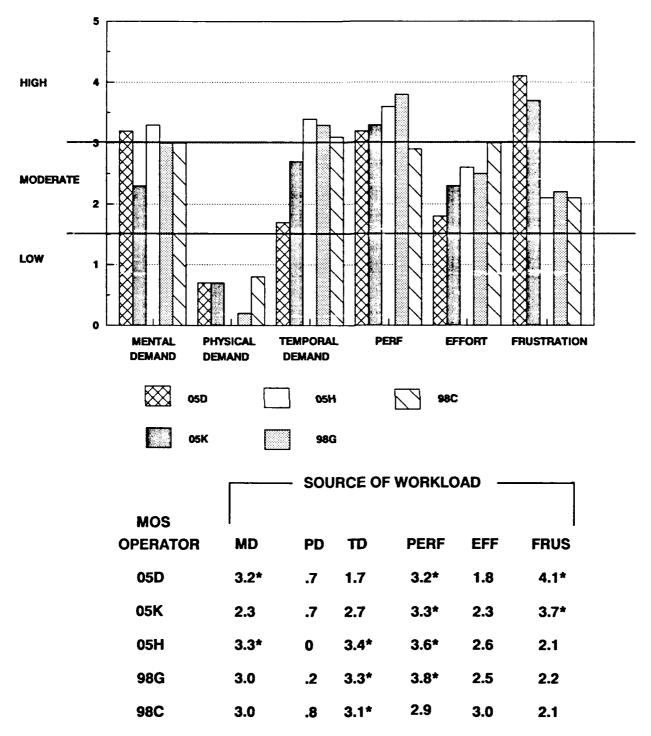
Source of Workload Profiles. Overall workload profiles for each operator position is shown in Table 3, which contains a chart of source of workload by operator position, and a bar graph plot of the source values. From these data, it can be seen that the preponderance of workload on these systems involves mental demand, temporal demands, performance concerns, and work frustration. Physical demands play very little role, and effort (how hard an individual has to work to achieve goals) is a borderline issue. Operators differ on which components are more critical: mental demand is only at a high level for 05D and 05H; temporal demand is at a high level for 05H, 98G and 98C; and frustration is highly critical in operator positions 05D and 05K. The collector MOS (05D, 05K, 05H, 98G) are all concerned with the performance dimension, that is how much is their work meeting the goal (providing the needed raw data to the analyst)?

Task Workload Values. Workload values by operator task are shown in Table 4. Values above 40.0 are considered high workload. Sixteen tasks were rated high workload by operators as indicated by asterisks in the table. The majority of high workload tasks occur in MOS 05H, 98G, and 98C. MOS 05D has the most total tasks (13), but only four are judged high workload. MOS 05K, with only three primary tasks, has no high workload; MOS 05H with three very

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Table 2

Sources of Workload for NASA-TLX Scale

TITLE	ENDPOINTS	DESCRIPTION
Mental Demand	Very Low/Very High	How mentally demanding was the task.
Physical Demand	Very Low/Very High	How physically demanding was the task.
Temporal Demand	Very Low/Very High	How hurried or rushed was the pace of the task.
Performance	Perfect/Failure	How successful were you in accomplishing what you were asked to do.
Effort	Very Low/Very High	How hard did you have to work to accomplish your level of performance.
Frustration	Very Low/Very High	How insecure, discouraged, irritated, and annoyed were you.

Table 3

Sources of Workload Profiles for Each Operator MOS

		SOURCE OF WORKLOAD				
MOS OPERATOR	MD	PD	TD	PERF	EFF	FRUS
05D	3.2*	.7	1.7	3.2*	1.8	4.1*
05K	2.3	.7	2.7	3.3*	2.3	3.7*
05H	3.3*	0	3.4*	3.6*	2.6	2.1
98G	3.0	.2	3.3*	3.8*	2.5	2.2
98C	3.0	.8	3.1*	2.9	3.0	2.1

*HIGH WORKLOAD WEIGHT ON THIS SUBSCALE

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Table 4

Workload Measures by Operator Task

05D (N=7)		Overall Workload Value
1.	Receive a tip.	34.9
2.	Tune receiver to frequency & locate signal.	17.0
3.	Prepare location request & pass to operator.	38.7
4.	Take LOBs.	28.7
5.	Edit LOBs.	21.0
6.	Get a fix.	16.9
7.	Communicate fix to net controller.	14.7
8.	Log targets (fixes).	26.1
9.	Communicate targets to traffic analyst.	44.2*
10.	Set up system, including antennas.	54.7*
11.	Perform system check with known targets.	31.5
12.	Troubleshoot, correct system & operator errors.	63.1*
13.	Communicate with outstation (to initialize system).	58.3*
05H (N=7)		
14.	Search & locate Morse signal.	48.6*
15.	Listen & copy Morse code.	53.9*
16.	Print traffic file.	46.1*

Table 4 (continued)

05K (N=3)

17. Search & Locate non-Morse signal.   35.6

18. Set up system for digitizing.   26.3

19. Print traffic file.   24.7

98G (N=4)

20. Search & locate voice signal.   36.2

21. Determine if signal of interest.   40.0

22. Record signal.   25.7

23. Listen, translate, transcribe into
     report mask.   55.3

24. Identify unit & activity with working
     aids.   65.2

25. Transcribe & write Strum report.   55.1

98C (N=7)

26. Log traffic from received printout.   20.0

27. Determine if reportable traffic.   44.2*

28. Identify unit & activity using working
     aids.   50.7*

29. Prepare report.   39.7*

30. Prepare tasking for all intercept
     operators.   50.9*

31. Update & create working aids.   44.3*

*High workload task

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similar tasks, rated all three tasks as high workload. MOS 98G
(six tasks) indicated that 67% of their tasks were high workload,
and MOS 98C (six tasks), 83%.

It appears on the surface that for the operation of the
baseline systems, the MOS 05H is the most demanding, followed by
98C, 98G, 05D, and 05K. Referring back to Table 3, it can be seen
that the source of workload for 05D and 05K is primarily
frustration and performance concerns. This could indicate that
these two MOS are concerned primarily with the functioning of
their equipment, which frequently causes frustration (see Table
1), and concern for whether performance goals (required outputs)
are being achieved. Another source of workload for 05D is mental
demand. This can be traced to the tasks relating to
troubleshooting and communicating (tasks 9, 10, 12, 13) in order
to get the system to work. The large number of citations on this
in the observational data of Table 1 corroborates this finding.

MOS 05H also indicated high mental demand. It is clear that
discrimination and copy of Morse Code is a process which involves
considerable mental effort, not only in the copy task but also in
receiving signals, editing, and transmitting copy (see Table 1).
The job appears to be a hybrid between equipment-oriented tasks
such as those of the 05D and 05K, and the more "cognitive"
(thinking) type work performed by 98G and 98C. Detection of non-
Morse signals as in the MOS 05K is a more automated, technical,
equipment-driven activity, as is direction-finding for the 05D.
The MOS 05H, 98G, and 98C require analysis of language and speech
patterns and their meaning. Although Morse Code is not a
"language," apparently the mental demands for processing it
(pattern recognition) are similar.

MOS 98G and 98C indicate high workload for the majority of the
tasks that characterize their positions. Although these are
highly analytical in nature, it can be seen from Table 3 that the
main sources of 98G and 98C workload are not mental demands,
however, but temporal demands. This may indicate that, since the
heavy analytical component is so much a part of the job and their
training process, that operators are suited for and become good at
it; but time pressures can seriously impact their system
performance capability.

Psychological Difficulty Analysis. The 31 system tasks were also
assessed for psychological difficulty by translating each task
into human performance elements and categories, then assigning
low, medium, or high ratings for each based on known difficulty
levels from human performance literature (adapted from Wickens,
1979). These difficulty level ratings are based on scale values of
human performance task elements (cognitive, psychomotor, visual,
and auditory) as shown in Table 5. In addition to scale values
within performance task category, it is known that cognitive task

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Table 5

Human Performance Elements and Associated Difficulty Levels

Human Performance Elements	Difficulty Levels

PSYCHOMOTOR

Activate (buttons, switches)	Low
Adjust - discrete (knobs, dials)	
Speech using prescribed format	
Adjust - continuous (e.g., flight controls)	
Manipulate objects (e.g., maps)	
Enter data (with keyboard)	
Write	↓
Speak/commo ideas in unstructured format	High

VISUAL

Monitor, scan	Low
Detect movement and change	
Trace, track	
Align, aim, orient on	
Discriminate symbols	
Discriminate patterns	↓
Read	High

AUDITORY

Detect occurrence of sound	Low
Detect change in amplotude, pulse, pitch	
Comprehend semantic content of message	
Discriminate sounds on basis of pattern, pitch,	↓
pulse, amplitude	High

COGNITIVE

Compare and associate	Low
Encode, decode	
Formulate plans, project actions	
Evaluate options	
Estimate, calculate	↓
Predict, infer	Very High

NOTE: In general, cognitive elements are of greater difficulty than psychomotor, visual, or auditory (from Wickens, 1984).

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elements are by nature more demanding than psychomotor, visual, or auditory. Table 6 lists the findings from this analysis showing the 31 operator tasks, associated human performance elements and identifiers, and difficulty level. Also shown is MOS and skill levels required for each task. The MOS data was drawn from critical task lists, soldier's manuals, and AR 611-201.

The psychological difficulty analysis indicates that there were 14 system tasks containing high or very high difficulty human performance elements (indicated by asterisks in Table 6). Twelve of these were also high workload tasks as judged using the NASA-TLX scale described above and shown in Table 4. The two tasks showing high psychological difficulty but not high workload, tasks 17 and 20, are "search and locate signal" for the MOS 05K and 98G, respectively. It appears that the automation technology for the 05K, and the discrimination experience of the 98G counter the inherent difficulty in actually performing these tasks.

Also notable from this analysis is the number of tasks containing a cognitive behavioral element. These are by nature more difficult and mentally demanding than tasks that contain primarily psychomotor, visual, or auditory elements. Seven tasks contain cognitive elements: three 05D tasks (10, 11, 12), one 98G task (24), and three 98C tasks (28, 30, 31). The cognitive demands of the 05D tasks corroborate the mental demand cited by the 05D operators and shown in Table 3. As stated in the analysis of the workload scores, these tasks center on troubleshooting, and on placement and alignment of system antennas, (system set-up) and involve considerable mental effort to get the system to "work." The cognitive demands of the 98G and 98C match closely the job and MOS descriptions that characterize these functions. These are not necessarily a cause of high workload, though, since this is an overt part of the training of these operators.

Four tasks were judged to have high workload but did not show high psychological difficulty (tasks 9, 13, 16, and 29). Examination of these shows that two relate to communication (9 and 13), task 16 relates to printing files off the system, and task 29 to report writing into report masks. These could be related to difficulties in getting the hardware to work as opposed to actual task difficulty if the system were functioning well. Comments on these points were made in the observationa. and interview section of Table 1, especially for the two (9 and 13) 05D tasks.

MOS Match to System Tasks. MOS tasks as defined in AR 611-201, critical task lists, and soldier manuals were then compared to the workload and task difficulty ratings (see Table 7). Particular attention was paid to coverage for the high workload and difficult tasks. In the current MOS inventory, all systems tasks are covered by the five MOS but at varying skill levels. In some cases, two MOSs can perform the same basic task, such as "listen

Table 6

Baseline System Tasks for Consideration in TRACKWOLF, Current MOS Match, and Psychological Difficulty Associated With Each Task.

PROJECTED TASK	MOS MATCH (1)	HUMAN PERFORMANCE ELEMENT (2)	DIFFICULTY LEVEL
1. Receive a tip over commo device.	05D10	Comprehend Message (A) / Activate & Adjust (P)	Medium / Low
2. Tune receiver to frequency & locate signal.	05D10	Activate & Adjust (P) / Detect (A)	Low / Low
3. Prepare location request & pass to operator	05D10, 05D20	Enter Data (P)	Medium
4. Take LOBs.	05D10, 05D20	Activate (P)	Low
5. Edit LOBs.	05D20	Activate & Adjust (P)	Low
6. Get a fix.	05D10, 05D20	Activate (P)	Low
7. Communicate fix to Net Controller.	05D10, 05D20	Speech Formatted (P)	Medium
8. Log targets (fixes).	05D10	Enter Data (P)	Medium
9. Communicate targets to traffic analyst.	05D10, 05D20	Activate & Adjust (P) / Speech Formatted (P)	Low / Medium
10. Set up system & system antennas.	05D10, 05K10	Manipulate Objects (P) / Estimate, Calculate, Predict (C)	Medium / Very High *
11. Perform system check with known targets.	05D10, 05D20	Activate & Adjust (P) / Compare & Associate (C)	Low / Low
12. Troubleshoot, correct system & operator errors.	05D10, 05D20	Activate & Adjust (P) / Estimate, Predict, Infer (C)	Low / Very High *
13. Communicate with outstation (to initialize system).	05D10	Activate & Adjust (P) / Speech Formatted (P)	Low / Medium
14. Search & locate Morse signal.	05H10	Discriminate Sounds (A) / Adjust (P)	High / Low *
15. Listen & copy Morse code.	05H10, 05K10, 05D10	Discriminate Sounds (A) / Enter Data (P)	High / Medium *
16. Print traffic file (Morse).	05K10	Activate (1) / Manipulate (P)	Low / Medium

Table 6 (continued)

PROJECTED TASK	MOS MATCH (1)	HUMAN PERFORMANCE ELEMENT (2)	DIFFICULTY LEVEL
17. Search & locate non-Morse signal.	05K10	Adjust (P); Discriminate Sounds (A) Discriminate Pattern (A)	Low, High High *
18. Set up system for digitizing.	05K10	Activate (P) Adjust (P)	Low Low
19. Print traffic file (non-Morse).	05K10	Activate (P) Manipulate (P)	Low Medium
20. Search & locate voice signal.	98G10, 98G20	Discriminate Sounds (A) Adjust (P)	High * Low
21. Determine if voice signal of interest.	98G10, 98G20, 98G30	Comprehend Semantic Content (A)	High *
22. Record voice signal.	98G20	Activate, Adjust (P)	Low
23. Listen, transcribe voice traffic.	98G10	Comprehend Semantic Content (A) Write (P)	High * High
24. Identify unit & activity with working aids.	98G10, 98G20	Correlate, Compare (C); Infer (C) Manipulate Objects (P)	Low; Very High * Medium
25. Transcribe & write Strum report.	98G10, 98G20	Write (P)	High *
26. Log traffic from print-outs.	98C10, 05H10, 05D10	Enter Data (P)	Medium
27. Determine if traffic is reportable.	98C10	Monitor, Scan (V) Read (V)	Low High *
28. Perform analysis, identify unit & activity.	98C10, 98C20	Encode, Decode (C); Discriminate Patterns (V); Predict, Infer (C)	Low High; Very High *
29. Prepare analytical report.	98C20	Enter Data (P) Write (P)	Medium Medium
30. Prepare tasking for intercept operators.	98C30	Formulate Plans, Project Actions (C) Evaluate Options (C)	Medium High *
31. Update & create marking aids.	98C20, 98C30	Formulate Plans (C); Write (P) Manipulate Objects (P)	Medium; High * Medium

(1) Data obtained from AR 611-201, Soldier Manuals, Critical Tasks Lists.
(2) Adapted from Wickens, 1984.

* High Level of Difficulty Task

Table 7

Composite of MOS Tasks as Selected and Trained (From Critical Tasks, Soldier's Manuals, AR 611-201)

05H Tasks for electronic warfare/signal intelligence interceptor Morse interceptor	05K Tasks for electronic warfare/signal intelligence non-Morse interceptor	98C Tasks for electronic warfare/signal intelligence analyst
05H10 **Operations** Detects, acquires, identifies, and records foreign communications. Performs duties in deployment, employment, and redeployment of unit in a tactical intermediate role. Performs electronic support measures for EW operations. Operates communication equipment for EW/SIGINT reporting and coordination. **Data analysis** Performs collector analysis and reports irregularities and suspected items of intelligence interest. Recognizes changes to transmission modes and informs the appropriate analytical or intercept station. **Administration** Completes intercept forms and logs. Records specific data entries on record copy of recorded communications to facilitate follow-up processing and analysis. **05H20** **Data analysis** Provides interceptor evaluation or current mission objectives to supervisor. Performs advanced collection analysis and assistance in the training of assigned personnel (OJT).	**05K10** **Operations** Searches radio frequencies to collect and identify target communications. Maintains intercept logs and prepares technical reports. Distinguishes aurally and visually between common types of simplex and multiplex radioteletype, facsimile, and data transmissions. Performs elementary analysis to determine signal parameters for signal identification. Copies Morse code communications when used in association with other modes of communications. Selects, erects, and orients tactical antennas. **05K20** **Operations** Uses special electronic equipment to perform complex signal analysis. Recognizes and reports items of intelligence interest. **05K30** **Supervision and management** Insures that incoming target tip-offs are responded to in appropriate priority. Insures that prompt and accurate tip-offs are provided to other mode collection activities. Coordinates interaction with other data collection and processing activities	**98C10** **Analysis** Gathers, sorts, and scans intercepted messages and traffic. Performs initial analysis to establish target communications patterns and order of battle. Isolates valid message traffic. Translates target communications data into automatic data processing (ADP) format. Maintains analytical working aids to support traffic collection, identification, and location. Performs duties in the deployment, employment, and redeployment of the unit in a tactical support role. Performs ESM for EW operations. Operates communications equipment. **98C20** **Analysis** Analyses foreign communications, including enciphered communications. Uses data processing techniques in intelligence production. Prepares technical and tactical intelligence reports.
05H30 **Supervision and management** Directs activities to fulfill essential elements of information requirements. Evaluates EW/SIGINT personnel and mission tasking. Implements EW/SIGINT emergency action plans. **Operations** Operates equipment configured for general mission detection, acquisition, and control. Assists in the formulation of plans for intercept-site surveys and conducts site tests. **Administration** Maintains intercept files and records.	**05K40** **Supervision and management** Insures proper handling of perishable intelligence information. Recommends changes in SIGINT missions. Performs SIGINT collection site surveys.	**98C30** **Supervision and management** Devises methods for solving complex analytic problems and maintains associated files. Writes, edits, evaluates, and publishes EW/SIGINT reports incorporating all source intelligence. Coordinates with collection management activity to determine taskings. Implements EW/SIGINT emergency action plans. **98C40** **Supervision and management** Analyzes and evaluates intelligence data and releases SIGINT reports. Briefs analytical mission status. Manages the mission's processing, analysis, and reporting functions.
05H40 **Supervision and management** Interprets EW/SIGINT tasking. Allocates intercept and special identification techniques (SIT) personnel and equipment resources. Plans collection strategies to fulfill EW/SIGINT objectives. Conducts intercept/SIT mission briefings.		

Table 7 (continued)

05D
Tasks for electronic warfare/signal Intelligence emitter Identifier/locator

05D10

Operations

Selects, erects, and orients tactical antenna.

Performs electronic support measures (ESM) for EW operations.

Operates DF, AIT, and related cryptographic, communications, and electronic data processing (EDP) equipment.

Receives tip-offs on targets and tunes signals for optimum reception.

Obtains desired display on AIT monitor scope.

Records electrical characteristics of radio signals displayed on oscilloscope using light sensitive recorder.

Communications liaison activities

Forwards bearings and identification information to control center via secure communications systems.

Coordinates DF/AIT activities with intercept and analysis section.

Administration

Prepares and maintains DF/AIT operation logs and card files.

05D20

Operations

Establishes, plots, and evaluates bearings of probable locations of foreign transmitters.

Determines DF bearings and wave form oscillograms on target transmitters.

Communications liaison activities

Forwards DF information to station in net for acquisition of DF bearings.

Data analysis and evaluation

Classifies, analyzes, and evaluates observed bearings and wave form oscillograms of threat force transmitters.

Measures bands on oscillograms to determine ripple frequency, modulation, percentage, and duration of other effects.

Develops composite DF plots.

Integrates DF/AIT data according to tasking.

Monitors and evaluates quality of DF/AIT input and output for EDP support.

Administration

Maintains calibration records accuracy studies and statistical data at DF sites and in the DF net control.

05D30

Supervision and management

Performs the duties of the preceding level of skill and provides technical guidance to lower grade personnel in the accomplishment of their duties.

Establishes and maintains facilities and sites of DF site personnel.

Plans and implements EW/SIGINT emergency action plan.

Inspects antennas and other equipment for placement, alignment, and orientation.

Insures equipment is in proper operating condition.

Administration

Prepares and controls the quality of DF/AIT reports.

98G
Tasks for electronic warfare/signal Intelligence voice Interceptor

98G1L

Operations

Assists in installation of equipment.

Operates communication equipment for EW/SIGINT reporting and coordination.

Makes voice servicing announcements.

Identifies languages spoken in an assigned geographic area.

Categorizes foreign voice signals by activity type.

Scans written foreign language material, which is predictable in subject matter and language, for key words and indicators.

Provides translation assistance to nonlanguage-qualified analysts.

Extracts obvious essential elements of information from voice radio transmissions to support mission reporting requirements.

Performs electronic support measures for EW operations.

98G2L

Operations

Operates equipment configured to intercept and produce written records of nonstereotyped foreign voice radio transmissions.

98G3L

Supervision and management

Directs voice signal collection and processing activities.

Determines collection and processing priorities.

Identifies and performs limited analysis on nonclear voice and nonvoice signals.

Implements EW/SIGINT emergency action plans.

Operations

Operates sophisticated equipment configured to collect and simultaneously produce on-line activity records of complex foreign voice radio transmissions containing technical terminology, advanced grammar and syntax, and colloquial conversational forms.

98G4L

Supervision and management

Refines essential elements of information requirements for identification and extraction.

Performs voice intercept and processing of highly complex foreign voice radio transmission.

98G5L

Supervision and management

Evaluates and defines job requirements and system capabilities for communications intelligence (COMINT) linguist resources.

and copy Morse Code," "log traffic," and "identify unit and activity." MOS 05D skill level one is cited 23 times, many more times than the other MOS, but a lot of these requirements are equipment oriented and account for the greater number of 05D tasks. MOS 05K and 05H can perform system functions with skill level one personnel; MOS 98G and 98C require personnel that span skill levels one, two and three. The 05D MOS has a number of requirements for skill level two as well as skill level one. Even though the system is covered by existing MOS, the higher skill level requirements for the 98G and 98C are noteworthy if TRACKWOLF would place additional demands on these MOSs.

Summary of Findings

The observational findings and analysis of workload and task difficulty scores for the OUTS and TRACKFINDER systems provide key lessons learned and areas for alert in the TRACKWOLF system. Lessons learned from the baseline systems (documented in Table 1) largely focus on equipment failures, frustrations, interface design deficiencies, or lack of automation support where needed. This results in system downtime and communication difficulties in the processing and transmission of needed data. Often reported comments were that user manuals are too complex and unreadable for obtaining the rapid guidance needed for certain subtasks, certain hardware and software did not work, and system set up was too hard.

Workload scores (Table 3) obtained through operator judgments reflect high levels of a frustration factor traceable to working with the equipment, the documentation, and the connectivities to other positions. Collector MOS (05D, 05K, 05H, 98G) also reported that their own performance in meeting user goals (transmitting needed intercept data to analysts) was a concern. Equipment frustrations were particularly reflected by 05D and 05K since this was a key source of their workload score. Temporal demands of data transmission and analysis was cited by the 05H Morse collector, the 98G voice intercept, and the 98C traffic analyst.

Currently 50% of the baseline system tasks are reported to have high workload. This workload is accounted for largely by equipment frustrations, communication difficulties, concern by intercept operators about supplying needed data (meeting performance goals), and the pace of temporal (time) demands within the analytic functions. Almost 50% of operator tasks are also difficult due to inherent psychological difficulty. The heavy analytical component of the 98G and 98C jobs account for much of this high difficulty level, and require skilled operators who have little leeway in their resident or OJT (On-the-job-training) training processes for new tasks. The heavy analytic demand is reflected in the higher skill level requirements of 98G and 98C personnel needed to operate the system.

Recommendations

If TRACKWOLF is to be an improvement on the baseline systems, the automation technology involved must decrease operational difficulties, not create new ones. Therefore interactions with the system must be tailored to the specific function and not include extraneous capabilities and requirements. A recommended solution to accomplish this is to create function-oriented rather than operator-oriented workstations. This would mean interfaces and basic interactions would be generic and involve a common core of computer skills. Operator specific functions would be performed by calling up software applications and displays peculiar to the mission. An example of this in prototype was the Fireworks system configured by ESL (a west coast contractor). A generic type workstation would reduce training load currently experienced.

An important recommendation is to simplify work and eliminate duplications of effort (thus decreasing workload) either by upgrading existing automation or incorporating state-of-the-art automation technology. Therefore, the TRACKWOLF system and any associated TRACKWOLF training for operator personnel must show how the new technology offsets some of the manual work now being done, so that new mental demands and equipment frustrations are not created.

Another recommendation to decrease workload was to redistribute operator functions by shifting direction-finding for simple lines-of-bearing fixes to other collectors besides the 05D (05H, 05K, 98G), except in the case of difficult targets. This would disperse the equipment-related tasks strictly held by 05D, but could place undue burden on other operators unless automated efficiently. It appears that the collectors 05K and 05H could perform some of these tasks as they are not currently functioning above skill level one; the 05K in particular does not exhibit high workload and could seemingly increase their tasks. However, the 05H and 98G operators already see their workload as high. Placing additional functions on these individuals would not be advisable unless other tradeoffs were made. High mental workload in 05D tasks will presumably be offset by upgraded system automation in TRACKWOLF. It is important that this also include improved equipment reliability and decreased need for extensive troubleshooting.

A recommended solution to decrease cognitive load from the 98C is to give certain simple analytical functions, such as unit identification and location, to collectors by providing automation-assisted working aids and databases. This could require a shift in training emphasis, but could be fairly straightforward with the proper software tools.

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Finally, explore in some detail the functional differences between the MOS 05K and 05H. Since there appear to be significant differences in the workload estimations, the role of new or upgraded automation for each must be approached carefully to insure that 05K is fully and appropriately utilized and 05H is not overburdened further.

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